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METHOD OF OPERATING A ROCKET ENGINE USING HEAT EXCHANGE WITH HYDROCAR- BON FUELS

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This invention relates to an improved method for operating a rocket engine.

Rockets of the type employing engines powered by hydrocarbon-liquid oxygen fuel combinations are important militarily and for space explorations. As is well-known, increasingly greater performance goals are being set for these vehicles. From the military viewpoint, it is highly desirable that the smallest possible vehicle be employed having the capability of fulfilling essential defense requirements. For general space applications, the maximum possible performance that can be achieved from a rocket is most important for the attainment of ambitiously planned space assignments.

Because of the enormous energy required to lift and propel a rocket, the performance of any rocket is critically dependent on the characteristics and energy content of the fuel-oxidizer combination employed. The greater the available energy content of the propellant, the greater the pay load and delivery range of the rocket.

Hydrocarbon-liquid oxygen combinations have been widely employed with substantial success as rocket or missile propellants. These combinations, which can be burned in conventional combustion chambers at a temperature up to about 5850° F., generate great power and are also highly desirable from an economic viewpoint. The energy and performance requirements proposed for future rockets, however, is beyond the capability of hydrocarbon-liquid oxygen systems with the result that considerable research effort is presently being directed to the use of more sophisticated chemical propellants of higher energy content. Actually there are a number of known hydrocarbon-oxidizer combinations which have a very high energy content and from this viewpoint are far superior to the hydrocarbon-liquid oxygen systems. Unfortunately such high energy systems cannot be employed in conventional rockets because their combustion temperatures are so high that they will burn out the combustion chambers of such rockets and destroy the rocket itself.

Employing the fuel component to cool the combustion chamber walls via heat exchange techniques has long been practiced. To be effective, such a technique must keep the temperature of the combustion chamber walls below about 2000° F. High energy hydrocarbon-oxidizer propellants give calculated combustion chamber temperatures (shifting equilibrium, 68 expansion ratio) of about 7900° F. and thus imposed enormous cooling demands for cooling combustion chamber walls. To date, no effective process has been developed that permits the use of very high energy hydrocarbon-oxidizer propellants. Factors barring the extension of this technique include the limitation in the amount of heat that can ordinarily be removed by the heating and/or vaporization of the fuel. Indeed, in view of the extremely high temperature of the combustion chamber, it has been postulated that ordinary heat exchange equipment would either be inadequate in capacity or that the equipment would be quickly coked-up or blocked with hydrocarbon disintegration products produced by the searing temperatures.

A novel method has now been discovered whereby rockets and missiles may be operated using an extremely high energy hydrocarbon-oxidizer propellant without

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burning out the combustion chamber of said rockets. This method depends on a combination of factors as will be more fully set forth below. In addition to providing a most important advance in rocket technology, this discovery promises to very substantially improve the performance capability of existing rockets and missiles after some slight modifications are made therein.

In accordance with this invention, a rocket having a combustion chamber and a heat exchanger in heat exchanging relationship to the walls of said combustion chamber is operated on a high energy fuel-oxidizer combination by passing at least a portion of a hydrocarbon fuel selected from the class consisting of tetraisobutylene, triisobutylene and diisobutylene through said heat exchanger causing substantial depolymerization of said hydrocarbon to isobutylene with concomitant removal of a substantial amount of heat by the endothermic depolymerization reaction and thereafter burning said isobutylene and a fluorine-containing oxidizer represented by the following classes: nitrogen-oxygen-fluorine compounds, mixtures of oxygen and fluorine, oxygen fluorides, nitrogen-fluorine compounds, halogen fluorides, or combinations thereof, in said combustion chamber to power said rocket. A preferred combination includes at least one oxygen for every carbon in the combustion chamber.

The hydrocarbon fuel for this process, namely a hydrocarbon from the class consisting of tetraisobutylene, triisobutylene, and diisobutylene, or a mixture thereof is a critical feature of this process. In common with most hydrocarbons, the foregoing fuels can absorb sensible heat by a temperature increase and/or by vaporization. The amount of heat taken up on this way, however, is insufficient to keep the combustion chamber wall at a temperature which allows maintenance of its structural integrity. The outstanding feature of the particular class of hydrocarbons selected is that they can undergo complete depolymerization to isobutylene under the high temperatures encountered in the heat exchanger with the absorption of a large amount of heat because of the highly endothermic depolymerization reaction. Tetraisobutylene is the preferred fuel and it will absorb 955 B.t.u.'s (calculated at 900° F.) for each pound of tetraisobutylene that is depolymerized. Another extremely important characteristic of these fuels is that the depolymerization reaction is very clean and takes place easily at the high temperatures encountered. The rate of decomposition increases with increased temperature. Thus the amount of heat removed increases with an increase in temperature. The ease and cleanliness of the reaction are especially important characteristics of these fuels since they permit large volumes of fuel to be depolymerized in the heat exchanger without coking-up or blocking the heat exchanger.

It is essential that the oxidizer for this process be a fluorine-containing compound for use in combination with the noted hydrocarbons. The high energy fuel mixtures of this invention can utilize an oxidizer from the group represented by nitrogen-oxygen fluorine compounds, mixtures of oxygen and fluorine, oxygen fluorides, nitrogen-fluoride compounds and halogen fluorides. A particularly preferred combination contains at least one oxygen atom for every carbon atom burned in the combustion chamber.

The described fuel mixtures burn at temperatures in the order of 6500 to 8000° F. and produce temperatures at the walls of the combustion chamber in the order of 2000° F. or above. As previously noted, the combustion chamber of a conventional rocket vehicle cannot withstand the high temperatures developed by these fuel systems. It is only by employing in combination the endothermic characteristics of the particular hydrocarbons

disclosed to remove the heat rapidly together with the use of a heat exchanging technique that a workable rocket with a high energy fuel system can be achieved. The particular design of the heat exchanger is not important provided it permits the depolymerization reaction to take place for a sufficient amount of the fuel to effectively cool the walls of the combustion chamber.

In conducting this process, a sufficient portion of the hydrocarbon from the prescribed class is passed into heat exchange relationship to the walls of the combustion chamber of the rocket to provide the necessary cooling. The hydrocarbon undergoes the essential endothermic depolymerization to cool the combustion chamber plus some additional cooling by the absorption of sensible heat. The depolymerized fuel, now substantially isobutylene is remixed with uncirculated fuel and directed into the combustion chamber along with an oxidizer of the class noted above to produce a high energy propellant and is burned therein.

The following example illustrates a preferred embodiment of this invention.

A rocket vehicle is employed having a combustion chamber, fuel and oxidizer storage tanks and a heat exchanger positioned in heat exchanging relationship to the walls of the combustion chamber. Tetraisobutylene is employed as the fuel and an oxygen and fluorine compound as the oxidizer. On ignition of the rocket engine, at least a portion of the tetraisobutylene is passed through the heat exchanger to undergo depolymerization and absorb heat from the walls of the combustion zone. The heated and depolymerized tetraisobutylene, now essentially isobutylene, with some diisobutylene and triisobutylene, emerging from the heat exchanger is combined with the remaining fuel stream and passed into a feed line to the combustion chamber. Simultaneously, the oxidizer is fed into the combustion chamber in suitable proportions to mix and burn with the fuel and produce a high energy thrust. The heat absorption of the tetraisobutylene is capable of reducing the wall temperature of the combustion chamber to a workable level, making it possible to continuously operate the rocket engine for the required period of time employing this high energy fuel-oxidizer system.

Obviously, many modifications and variations of the invention, as hereinbefore set forth, may be made without departing from the spirit and scope thereof, and therefore only such limitations should be imposed as are indicated in the appended claims.

We claim:

1. A method of operating a rocket engine on a high

energy hydrocarbon-oxidizer propellant, said rocket engine having a combustion zone and a heat exchanger in heat exchanging relationship to the walls of said combustion zone, the improvement which comprises employing a hydrocarbon, from the class consisting of tetraisobutylene, triisobutylene and diisobutylene, and a fluorine-oxygen-containing oxidizer containing at least one atom of oxygen for every carbon atom in said hydrocarbon, and passing at least a portion of said hydrocarbon through said heat exchanger under conditions causing substantial depolymerization of said hydrocarbon to isobutylene effective to remove at least 900 B.t.u.'s for each pound of said hydrocarbon that is depolymerized and thereafter burning said depolymerized hydrocarbon with said oxidizer in said combustion zone.

2. A method according to claim 1 in which said oxidizer is selected from the class of nitrogen-oxygen-fluorine compounds, mixtures of oxygen and fluorine, and oxygen fluorides.

3. A method of operating a rocket engine on a high energy hydrocarbon-oxidizer propellant, said rocket engine having a combustion zone and a heat exchanger in heat exchanging relationship to the walls of said combustion zone and said propellant characterized by having a heat output effective to produce combustion temperatures in the order of 6500 to 8000° F. which substantially exceed the structural limits of the walls of said combustion zone, the improvement which comprises employing tetraisobutylene as said hydrocarbon and a fluorine-oxygen-containing oxidizer containing at least one atom of oxygen for every carbon atom in said tetraisobutylene, and passing at least a portion of said tetraisobutylene through said heat exchanger under conditions causing depolymerization of said tetraisobutylene and removal of about 955 B.t.u.'s for each pound of tetraisobutylene depolymerized, and burning said depolymerized tetraisobutylene with said oxidizer in said combustion zone.

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